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Optimization of the Forward Osmosis Process Using Aquaporin Membranes in Chromium Removal

Due to the lack of affordable and feasible wastewater treatment technologies, various industries in developing countries are discharging chromium (Cr) without meeting the environmental standards. Here, the aim was to employ forward osmosis (FO) using aquaporins (AQP)-based biomimetic membranes and optimize the Cr rejection through response surface methodology (RSM). The initial concentration of draw solution, feed solution, and time was selected as independent variables in order to optimize Cr rejection and water flux. A high Cr rejection efficiency and water flux were achieved under the optimal conditions. These results revealed that the FO process applying an AQP membrane beside the RSM could be considered to treat wastewaters containing heavy metals.

Keywords: Aquaporin membrane, Chromium removal, Forward osmosis, Response surface methodology

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1 Introduction

Industrialization has many advantages and helps the economic growth of countries, but it can put human health and environment at stake via discharge and accumulation of large amounts of chemicals to the environment. Contamination of the environment with heavy metals influences all creatures and poses a serious threat to both the environment and human beings [1–4]. Since heavy metals are non-degradable, they exhibit negative effects on the aquatic natural life and ultimately contaminate the food chain [2, 5].

Chromium (Cr) is one of the most poisonous heavy metals, which is produced in great amounts by several industries and can be discharged into the environment through wastewater. Cr is a gray, shiny, hard, and brittle metal and is extracted from chromite ore ($FeCr_2O_4$). When heated to chromium, chromic acid is formed, which is green and unstable. Cr exists in two forms, i.e., hexavalent Cr (Cr(VI)) and trivalent Cr (Cr(III)). Cr(III) is one of the essential nutrients for humans which is not as harmful to human health as is permissible. On the other hand, Cr(VI) as a hazardous environmental pollutant is much more toxic, and has a higher solubility and mobility than the other forms. Hence, it could cause adverse effects on all existences.

One of the most important issues of Cr(VI) besides its high toxicity is related to the bioaccumulation property of the liver, it causes kidney syndromes, and it can be deadly at concentrations above 0.1 mg L^{-1} [6, 7]. Previous works reported that the quantity of Cr(VI) in industrial effluents range from 0.5 to 270 000 mg L^{-1} [8]. Furthermore, according to the EPA report, Cr(VI) is an agent contaminant in broad aqueous stream pollution classifications with maximum contaminant levels of 100 µg L^{-1} [9]. Therefore, this carcinogenic heavy metal has to be treated prior to discharge into the environment [10].

There are a number of conventional techniques for Cr(VI) removal from industrial wastewaters and aqueous solutions, such as chemical precipitation, absorption, biosorption, ion-exchange, electrochemical method etc. However, these methods have major drawbacks such as low affordability, difficult application, and not being environmentally friendly [11, 12]. Membrane-based filtration technologies like reverse osmosis (RO) and nanofiltration (NF) have some advantages like high efficiency and ease of use [13], and have been extensively applied for the removal of heavy metals. In spite of the high efficiency

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